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Effects of an In-service Program on Biology and Chemistry Teachers' Perception of the Role of Laboratory Work

Eugénia Flora Rosa Cossa[a,]*, Amália Alexandre Uamusse[b]

[a]*EduardoMondlane University, Faculty of Education, Ave Julius Nyerere-Main Campus, Maputo 257, Mozambique*
[b]*EduardoMondlane University, Faculty of Science, Ave Julius Nyerere-Main Campus, Maputo 257, Mozambique*

Abstract

This study is based on the concept that an in-service training program can help teachers to better understand the importance of using laboratory work to teach science and thus, improve the level of performance of their students. The study was conducted by the facilitators before and after a five day training workshop and sought to understand the teachers' perceptions of and experiences with the aims of laboratory work and its importance in the teaching of Biology and Chemistry subjects. Seventeen secondary school teachers from both subjects were involved in the study. Overall, the findings of this study suggested that the teachers improved their level of understanding of the importance of using laboratory work to teach Biology and Chemistry subjects after attending a training workshop. Teachers recognize the value placed on laboratory work to familiarize students with the practical component; however, they feel that the lack of well equipped laboratories, in most of their schools, is a great barrier for them to conduct laboratory work of any kind in their classes. Teachers complained about the length of the Biology and Chemistry syllabuses and recommend a thorough revision if the Ministry of Education wants them to conduct laboratory work in their classes and hence, comply with its aims. The fact that most of the teachers during their initial training did not have laboratory work effectively resulted in the fragility and fear to use any kind of laboratory work. Therefore, the schools are urged to organize ongoing professional development programs that meet the teachers' specific needs.

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Keywords: laboratory work; in-service training; teachers' perceptions

* Corresponding author. Tel.: +258-82-4686060; fax: +258-21-493313.
E-mail address: eugenia.cossa@gmail.com

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1. Introduction and theoretical background

Studies in science education worldwide have recognized that laboratory work plays a central role in the teaching and learning of science concepts at different levels of educational systems (Motlhabane & Dichaba, 2013; Danmone, 2012; Hofstein & Mamlok-Naaman, 2007; Cossa, Holtman, Ogunniyi & Mikalsen, 2008; Al-Naqbi & Tairab, 2005; Blosser, 1990). However, according to the literature, in many countries of the world and particularly in the developing countries, the effective implementation of the laboratory work is a general problem accompanied by several constraints. For instance, the inexistence of adequate conditions and availability of equipment and laboratorial materials, including financial resources, to teach practical science, poor preparation of teachers, poor implementation of procedures, overwhelming number of activities demanded by the new curricula and lack of qualified teachers are some of the problems confronting the process of science teaching, particularly in African settings (Motlhabane, 2013; Bekalo & Welford, 1999; Hodson, 1992; Allsop, 1991). In addition, most of the experiments and laboratory activities are conducted using a 'recipe-style' in which the students are required only to follow a set of steps to demonstrate and verify the scientific concepts already known (Hodson, 1996). In relation to this, Woodley (2009:50) states that if the goals and objectives are not expressed in terms of being able to apply scientific knowledge, understanding and skills there is a danger of students simply following ´recipes` during practical activities. This way of doing laboratory work or practical work has been criticized for its distortion of what science really is, encouragement of rote learning rather than meaningful inquiry oriented learning and failure to provide students with opportunities to plan investigations and perform their own experiments, manipulate equipment and materials so that they can construct their own knowledge of phenomena and related scientific concepts (Hofstein & Mamlok-Naaman, 2007; Domin, 1999; Shiland, 1999; Hodson, 1996). Furthermore, another constraint, not less important, is the lack of a culture to carry out educational research in many science schools which can contribute to the teachers not having a well developed and clear vision of the aims to be attained through laboratory work in science (Cossa, 2007). It is presumed that this situation can in part lead to the teachers not being committed to the teaching of science through laboratory work.

This study is based on a professional development program designed at the Faculty of Education of the Eduardo Mondlane University with the aim of training in-service secondary school teachers in the areas of Natural Sciences and Mathematics. According to Guskey (2002) professional development programs are systemic efforts aimed at bringing about changes in the classroom practices of teachers, in their attitudes and beliefs, and in the learning outcomes of the students. For the study described in this article, a professional development program was designed with the premise of providing the teachers with opportunities to improve their practical knowledge and skills by integrating them with their experiential knowledge, formal knowledge and personal beliefs (van Driel, Beijaard and Verloop, 2001) and hence, improve their understanding about the role of laboratory work to teach Biology and Chemistry subjects. In addition, it assumed that investigating the teachers' perceptions of the role of laboratory work to teach science will help to improve the design of the teacher training programs aligned with their specific subject needs (Sahin-Pekmez, 2005).

As for many developing countries, in Mozambique laboratory work fails because of poor practical skills of the science teachers, lack of time to plan science activities and experimental work and the system of examinations that gives more focus on theory and less emphasis on practical work (Allsop, 1991; Woolnough, 1991). In addition, due to the shortage of funds, laboratory equipment and learning materials are in short supply. Consequently, teachers tend to organize laboratory activities rather sparingly or regard practical work as not being important to promote positive attitudes towards science (Cossa, 2007). For the purpose of this study and considering the context in which the study took place, the term 'laboratory work' is used as a synonymous of 'practical work' to refer to classroom laboratory activities that include teacher demonstrations, discussions, simulations, exercises, observations or manipulations of real objects and materials by students and fieldwork. As indicated in the literature, the terms laboratory or practical work have been used too often without exact meaning to embrace a wide range of practical or laboratory activities (Hofstein & Mamlok-Naaman, 2007). For instance, Woodley (2009) categorizes practical work into two main categories: (i) core activities which encompass investigations, laboratory procedures and techniques, and fieldwork; and (ii) directly related activities covering teacher demonstrations, experiencing phenomena, designing and planning investigations, analyzing results, and data analysis using ICT. According to this author, while the first category represents hands-on activities which support the development of practical skills, and help to

shape student`s understanding of scientific concepts and phenomena, the second category is considered as being closely related to the core activities and provides valuable first-hand experiences for students.

2. Objectives of the study

The study conducted during an in-service program explored the teachers' perceptions of and experiences with the aims of laboratory work and its importance in the teaching of Biology and Chemistry subjects in secondary schools of the Zambezia province, in Quelimane city. Specifically, the study intended to explore the teachers' experiences and views on the current practices and frequency of use of laboratory work as well as their perceptions of the aims of laboratory work in the teaching of Biology and Chemistry subjects. In this regard, the following research questions guided the study:

a) What are the teachers' experiences of and views on the current practices and frequency of use of laboratory work to teach Biology and Chemistry subjects?

b) What are the teachers' perceptions of the aims of laboratory work in the teaching of Biology and Chemistry subjects?

3. Research methodology

As stated early, the study was conducted during an in-service teaching training program aimed at providing teachers with new inputs about the importance of using laboratory work in the teaching of Biology and Chemistry subjects. The study involved 17 senior secondary school Biology and Chemistry teachers from the Zambezia province. The teachers were purposefully selected in consultation with the school administrators. In all, seven were teaching Biology, eight Chemistry and two taught both subjects. Their age ranged from 25 to 42 years old and only two Biology teachers were female. In terms of the academic level, ten teachers hold a bachelor degree, six honors and only one another qualification.

The study used participatory methodologies such as small group discussions, brainstorming and presentations at plenary sessions. The study comprised three phases: administration of a pre-test, training workshop and administration of a post-test. Thus, teachers' perceptions questionnaire (TPQ) adapted from the instrument used by Cossa (2007) was administrated before and after the training workshop, which lasted five days. The questionnaire, consisting of closed and open questions required the teachers to show their experiences and opinions about the current practices, frequency use of laboratory work and its aims. Regarding the training workshop, the initial part was devoted to discussing with the participants the importance and types of laboratory work in the teaching of science including the safety norms and techniques to be observed in the laboratory. In groups of 4 to 5, teachers discussed the strengths and weaknesses of the laboratory work and identified at least five types of laboratory work: observation, discovery, practical skills, investigation and illustration. In addition, participants were asked to interpret the meaning of the norms (R = Risk; S = Security) indicated in the tags of the bottle containing chemicals. For the next days of the training, participants were divided according to their subjects to be trained in the specific laboratory experiments and content. Thus, the biology teachers were trained on how to: (i) prepare microscope slides using onion epidermis cells; (ii) how to use light microscope to observe cells; and (iii) how to simulate mitosis and meiosis using pupils as chromosomes. The chemistry teachers were first asked to identify laboratory experiments they can do in their schools using local material. As a result, they were trained in the following: (i) use of natural indicators; (ii) rate of heterogenic chemical reaction; (iii) identification of carbon dioxide in a solution; (iv) identification of iodide ion; and (v) reaction of sodium carbonate with vinegar and 5% acetic acid. On the last day teachers were asked to evaluate the training workshop, taking into account their expectations from the first day and the objective of the workshop.

The data emerged from the TPQ were analyzed using descriptive statistics using excel. Thus, tables of frequencies were generated from the quantitative data. The qualitative data resulted from the teachers' comments

were categorized and analyzed according to their similarities and differences. The teachers' responses that emerged from the evaluation sheet were used to complement the findings from the TPQ.

4. Results and discussion

1.1. Teachers ' opinions about the current practices

With regard to the number of times they teach using laboratory equipment or materials (eg: microscope, water, specimens, chemicals), before the training workshop, three of the 17 respondents indicated that they were not able to teach in a room with laboratorial equipment and materials. Five respondents indicated that they were able to teach once a week, three said twice a week and only two had this occasion three times a week. After the training workshop the respondents did not change their opinions concerning the number of times they are required to teach in a room with laboratory equipment and materials showing consistency in their responses. Regarding the use of their laboratory to teach normal classes, that is, as a classroom, before and after the workshop, nine respondents said that they use their laboratories for the theoretical lessons while seven said that they did not use its laboratories as a classroom. Three of the respondents indicated that the average number of students in class ranges from 10 to 25 per session. Eight respondents pointed to a variation of students from 50 to 80 per session. They feel that this number of students has a negative impact because there is no way of conducting laboratory classes with quality and pay attention to the individual needs of the students, as indicated in their comments. Furthermore, they claimed saying that the laboratory classes occur with many difficulties due the lack of materials and adequate space as well as training on how to perform laboratory experiments. These comments are in line with what other scholars have stated in their studies regarding the poor conditions, insufficient equipment, long preparation time and lack of proper training and background to carry out laboratory work (Motlhabane, 2013; Sahin-Pekmez, 2005).

Yet in their comments, one of the teachers said that "some of the schools have laboratories with minimal conditions, but they are not used, teachers do not feel confident because of the lack of training since their initial education". He continued by saying that "in case there are no laboratories in the schools, we try to do practical work using local and low cost materials in chemistry classes". Nine respondents agreed in their comments saying that "the laboratory work leads the student to a better familiarity with the practice, but with the lack of laboratories and/or laboratory materials, laboratory work cannot occur". Another three teachers commented that "occasionally they improvise laboratory activities; so they can work, but rarely". They also revealed that the use of local material to minimize the situation has been a success. Analyzing these comments, it is notable that, to some extent, teachers have the willingness to teach biology and chemistry content using laboratory work despite the inadequacy of the conditions that are exposed in their schools. It can be seen that teachers believe that laboratory work is important as it familiarizes the students with the practical component and hence, develop their manipulative skills to use equipment and materials in order to be able to construct their own knowledge of phenomena and related scientific subjects (Hofstein & Mamlok-Naaman, 2007).

4.1 Teachers' views of the frequency of use of laboratory work

In this section the respondents were asked to indicate the 'frequency of use' of various types of laboratory work taking place in biology and chemistry classes before and after the training workshop. These included demonstrations, observation or manipulation of real objects and materials by the students and laboratory field work. The results in Table 1 show the number of the respondents using each type of laboratory work in five categories: never used, rarely used, occasionally used, used and frequently used. To make the process of analysis more practical, the first three categories were grouped as "Never or occasionally used" and the last two as "Used or frequently used" indicating negative and positive responses, respectively.

Table 1. Frequency of use of different kinds of laboratory work

Kinds of practical work	Never or Occasionally used		Frequently Used	
	BTW	ATW	BTW	ATW
Demonstrations that verify facts and principles	7	6	6	6
Experiments by students or lecturer to illustrate or reinforce concepts and theories taught in tutorials	10	4	6	8
Laboratory work set to familiarize students with the use of important instruments, equipment, and techniques	15	10	1	3
Laboratory work that enables the teaching of procedures or skills to manipulate and design experiments	16	11	1	2
Laboratory work which motivates students to develop positive attitudes towards biology and chemistry subjects	13	5	4	7
Laboratory work that introduces students to the world of science	15	11	1	2
Problem-solving or discovery experiments (by lecturer or student) designed to answer a question raised during tutorials	12	7	4	6
Investigations of the problems performed by student(s); not necessarily connected in a direct way to the theoretical course	16	11	0	2

N (BTW) =17; N (ATW) = 14; BTW = Before Training Workshop; ATW = After Training Workshop

Obs.: Some of the participants did not indicate their opinion regarding the frequency of use of laboratory work, the reason why the total is not equal to 17 and 14.

From the results in the table above it can be noted that, before the training workshop, most of the teachers were unanimous in their opinions indicating that they 'Never or Occasionally used' different types of laboratory work, with special emphasis on: Investigations of the problems performed by student(s) (16); Laboratory work that enables the teaching of procedures or skills to manipulate and design experiments (16); Laboratory work set to familiarize students with the use of important instruments, equipment, and techniques (15); Laboratory work that introduces students to the world of scientists (15); and Laboratory work which motivates students to develop positive attitudes towards biology and chemistry subjects (13). After the training workshop teachers changed their opinions significantly regarding the 'infrequent use' of the different types of laboratory work mainly for the laboratory work related to the experiments by students or lecturer to illustrate or reinforce concepts and theories taught in tutorials followed by the laboratory work which motivate students to develop positive attitudes towards biology and chemistry subjects, ten to four and thirteen to five, respectively.

When teachers were asked to evaluate the effectiveness of the training workshop, they agreed that the experiments they have performed during the training brought them a new impulse and improved their attitude to the need to perform laboratory work even without adequate infra-structure and conventional laboratory materials. They added that with the gained experience they will be able to stimulate their students to become interested in learning biology and chemistry content through laboratory work. However, contrasting this evaluation with the results in Table 1, one can see that the views of the teachers after the training workshop did not change as much concerning the use of the following types of laboratory work. An average of 11 teachers continued to say that they 'Never or Occasionally used': Laboratory work that enables the teaching of procedures or skills to manipulate and design experiments (11); Investigations of the problems performed by student(s); not necessarily connected in a direct way to the theoretical course (11); Laboratory work set to familiarize students with the use of important instruments, equipment, and techniques (10); and Laboratory work that introduces students to the world of scientists (11). The reason why most teachers continue to use these four aims infrequently can be linked to their comments in the previous sections which are in line with the results found in studies conducted by (Kerr, 1963, Bekalo & Welford, 1999, Fessehatsion, 2003). In these studies, it was found that the teachers do not use all different types of practical work on a regular basis or consistently. They normally ignore other types of practical work with the excuse of unconducive practical working conditions. Sometimes they prefer to use demonstrations, in detriment of experiments or vice-versa.

With regard to the number of times that their students are confronted with laboratory work of any kind in Biology and Chemistry classes, the teachers' responses suggested that the use of different kinds of laboratory work was rather limited before and after the training workshop. For instance, before the training workshop most of the teachers (14) of a total of 17 indicated never or rarely and only two said that they used any kind of laboratory work

once a week as indicated in the syllabuses. After the training workshop, seven of the teachers continued to say that they never or rarely used any kind of laboratory work in their classes. Three said that they used it once a week in two lessons while two said about once in two classes and three about once for every class. This may derive from the large number of students per section which makes it impracticable to do laboratory work for these educational professionals, as indicated in the previous sections.

Teachers were also asked to indicate the number of times they do laboratory work as fieldwork (eg: excursions and study visits) with their students. Before the training workshop, most of the teachers (14) were unanimous in their responses, indicating that they never did this activity while one and two said that they do this once per semester and per year, respectively. After the training work the number of the teachers doing fieldwork per year increased from one to four and the number of teachers not able to do fieldwork reduced from 14 to seven. This is a good indication that the training workshop contributed to teachers improving their understanding about the importance of laboratory work in the teaching and learning of science. In other words, the teachers' visions about the types and aims of laboratory work to teach science become clear despite their claims about the inadequate conditions offered by the schools. It is thought that the lack of equipment and chemicals as well as the laboratory itself for the execution of experiments might have contributed negatively to teachers not feeling motivated and confident in conducting laboratory work in their classes (Camuendo, 2006). For instance, one of the teachers commented that: "the use of laboratory work has no longer been the practice in his school; he added saying that sometimes they do excursions more often than the laboratory work of biology and chemistry classes, as these do not need more resources".

Furthermore, the teachers claimed in their comments that: "the biology and chemistry syllabuses are too extensive, as a result teachers choose not to move forward with the laboratory lessons due to pressure to accomplish the course outline". In parallel to this, most of the biology and chemistry teachers that attended the in-service training program expressed their feeling saying that: "during their initial training they did not have effective laboratory practices; hence their fragility in teaching using laboratory classes". In this regard, authors like Gonçalves (2009) and de Feiter, Vonk, and van der Akker (1995) caution that when the teacher ends his initial training and enters the classroom, he goes through several stages that characterize his professional development (eg: induction, adaptation, maturation, leadership). The lack of ongoing monitoring during the passage through these phases may contribute negatively to the teachers' performance in the classroom. Thus, it becomes imperative that the teacher be trained through a continuous and long process taking into account the emerging needs during the stages of his professional career.

4.2 Teachers' views of the aims of laboratory work

In this section, teachers were required to rate each of the ten aims of laboratory work in biology and chemistry in terms of their importance in three categories: "Least important", "Important" and Most important". The ten aims selected for this study were adapted from the study conducted by Cossa (2007) as a result of a set of 20 aims produced by Beatty & Woolnough (1982). The results in Table 2 show the teachers' rankings of the importance of the aims of laboratory work before and after the training workshop.

Before the training workshop, most of the respondents considered aims 6, 4 and 9 as the most important as follows: (i) to verify or clarify events and principles already taught in tutorials explaining their relationship (12); (ii) to elucidate the theoretical work as a means of helping understanding (10); and to discover facts and come up with new principles (9). However, only five respondents regarded aim 3 'to make science more interesting and fun through current experiences' as the least important.

After the training workshop the respondents' opinions varied significantly. Apparently, there is a relative equilibrium between their opinions in the two categories 'most important' and 'important' in some of the aims. Thus, the first six most important aims they nominated were: (i) to gain practice of making observations and descriptions of objects (7 respondents); (ii) to promote the method of reasoning and logical thinking in problem-solving (7 respondents); (iii) to make science more interesting and fun through current experiences (6); (iv) to make the biological/chemical phenomena more real through actual experience (6); (v) to verify or clarify events and principles already taught in tutorials explaining their relationship (6); and to discover facts and come up with new principles (6). These results differ to some extent from those indicated by the teachers in the Swain *et al*. (1999) study. For instance, the Korean teachers indicated the five most important aims as follows: (i) for finding facts and

arriving at new principles; (ii) as a creative activity; (iii) to verify facts and principles already taught; (iv) to elucidate theoretical work as an aid to comprehension and; (v) to help remember facts and principles. Comparing these results with the results of the study described in this paper, it can be seen that the aims indicated by the Korean teachers were more content focused, while the Mozambican biology and chemistry teachers tend to be more orientated towards both content and investigative views, indicating a balance between their perceptions of the importance of using laboratory work in the teaching and learning of science content despite the poor conditions in their schools.

In addition and interesting to be noted is that, despite the fact that teachers perceived most of the aims of laboratory work as 'important' and 'most important', before and after the training workshop, they regarded aims 3 and 10 'to make science more interesting and fun through current experiences (5)' and 'to provide students with opportunities to practice necessary skills or procedures (4)' as the 'least important', respectively. The reasons why these teachers think so might be associated to the lack of adequate knowledge of the role of practical work, especially procedural understanding (Sahin-Perkmez, 2005) in terms of knowing that when the students do practical work they can become more interested in learning science, gain some basic skills to use laboratory materials as well as develop positive attitudes toward science. In addition, the lack of well equipped laboratories, materials and chemicals, large classes and syllabuses can lead the teachers to regard some of the aims as less important. According to Swain, Monk, & Johnson (2000) and Hofstein & Lunetta (2003) conditions like these do not provide teachers with opportunities to use laboratory work in their classes and consequently, students do not have the opportunity to perform their own observations, investigations and experiments as a way to arouse interest in learning science subjects.

Table 2. Teacher rankings of the importance of ten aims for laboratory work

Aims of laboratory work	Least important		Important		Most important	
	BTW	ATW	BTW	ATW	BTW	ATW
1. To gain practice of making observations and descriptions of objects	0	1	10	4	7	7
2. To promote the method of reasoning and logical thinking in problem-solving	1	0	9	5	6	7
3. To make science more interesting and fun through current experiences	5	2	3	3	8	6
4. To elucidate the theoretical work as a means of helping understanding	0	2	6	6	10	3
5. To make the biological/chemical phenomena more real through actual experience	0	2	10	3	7	6
6. To verify or clarify events and principles already taught in tutorials explaining their relationship	0	2	4	4	12	6
7. To raise and maintain interest in the discipline of Biology/Chemistry.	1	1	11	5	3	5
8. To promote the understanding of the scientific methods or laboratory techniques	1	0	8	9	7	3
9. To discover facts and come up with new principles	1	0	7	6	9	6
10. To provide students with opportunities to practice necessary skills or procedures	2	4	10	4	4	4

N (BTW) =17; N (ATW) = 14; BTW = Before Training Workshop; ATW = After Training Workshop
Obs.: Some of the respondents did not indicate their opinion regarding the importance of each aims of laboratory work, the reason why the total is not equal to 17 and 14.

5. Conclusions and recommendations

Overall, the findings of this study suggested that the teachers improved their perceptions of the importance of using laboratory work to teach Biology and Chemistry subjects after attending a training workshop. For instance, in their comments, teachers said that laboratory work is a helpful means to teach science content as it familiarizes the students with the practical component. They recognized that the experiments performed during the training workshop improved their understanding and awareness concerning the need of using laboratory work even without adequate infra-structure and conventional laboratory equipment and materials. In addition, teachers share a common view that the experiences gained during the workshop will serve to stimulate their students to become more interested in learning biology and chemistry content through laboratory work. However, like in many other studies, teachers indicated that due to the inappropriate conditions that vary from the lack of adequate infra-structures, laboratory equipment and supplies, to overwhelming classrooms, time allocated to laboratory sessions and pressure to finish the extensive syllabus they were not able to use different kinds of laboratory work to teach in their classes.

Even though, after the training workshop teachers became more aware of the need of using different types of laboratory work, mainly the experiments designed by students and teachers to illustrate or reinforce the concepts and theories taught in tutorials as well as motivating the students to develop positive attitudes towards Biology and Chemistry subjects. In regard to the aims of laboratory work, the teachers' opinions changed significantly after the training workshop. Apparently, their opinions were symmetrically divided between important and most important aims. Important to note is that the perceived aims as the most important appear to be more oriented towards both content and investigative components when compared with the Korean teachers' views in the Swain *et al*. (1999) study. Concerning the length of the Biology and Chemistry syllabus teachers felt that there is a need of revision if the Ministry of Education wants them to conduct laboratory sessions in their classes and hence, comply with its aims. From the results of this study it is possible to see that there is a mismatch between the frequent use of the different types of laboratory work and views of the teachers concerning the aims of laboratory work. The fact that most of the teachers, during their initial education, did not have the chance to perform laboratory activities effectively resulted in the fragility and fear of using laboratory work of any kind, as was claimed by the teachers in their comments.

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